ANGST in the GROCERY AISLE

The Debate over Genetically Modified Foods

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http://ucbiotech.org
http://pmb.berkeley.edu/profile/plemaux#a1

The debate over GMO's has gone on for some time.

But is public concern just about genetically engineered foods (GMO's)?

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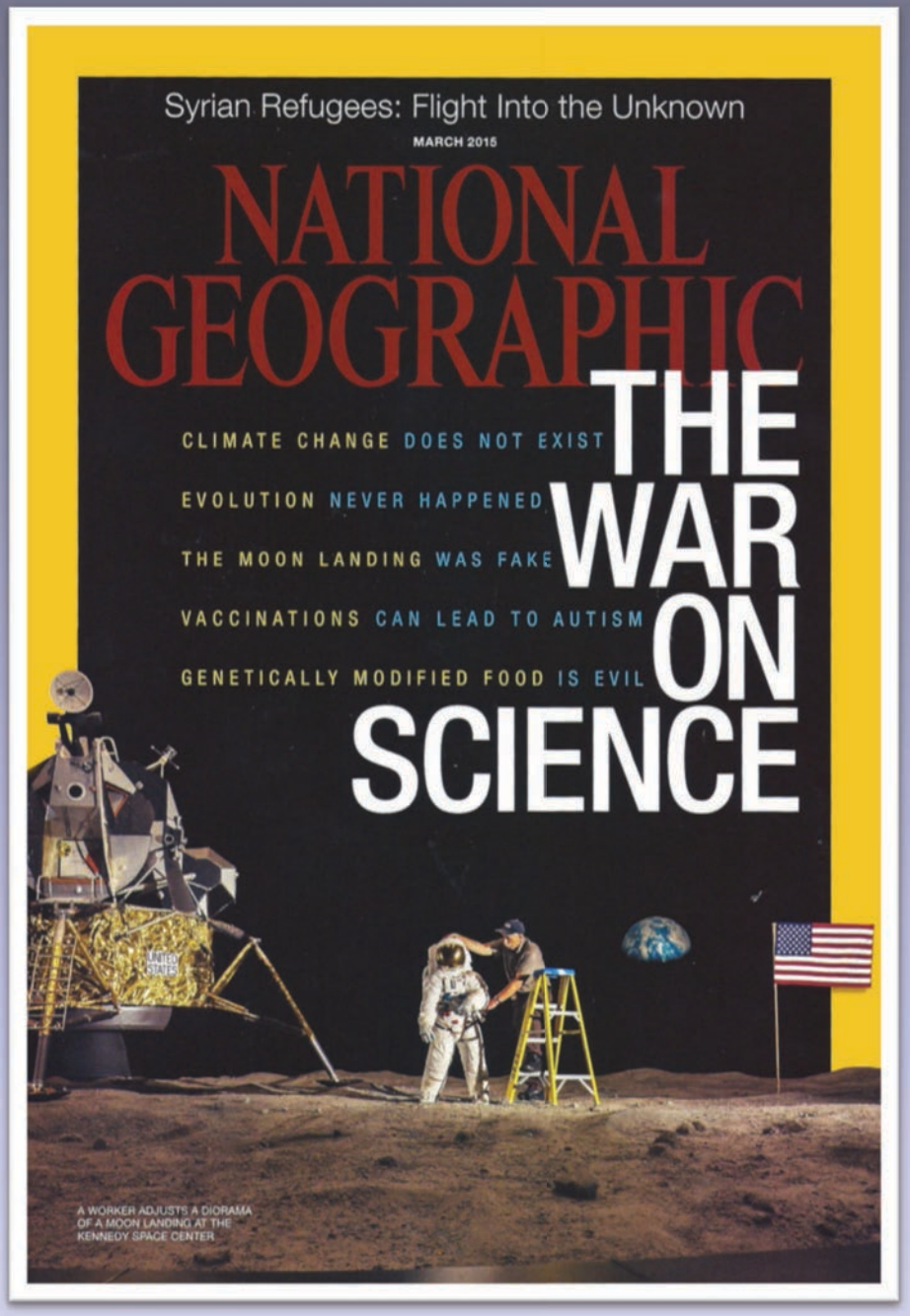


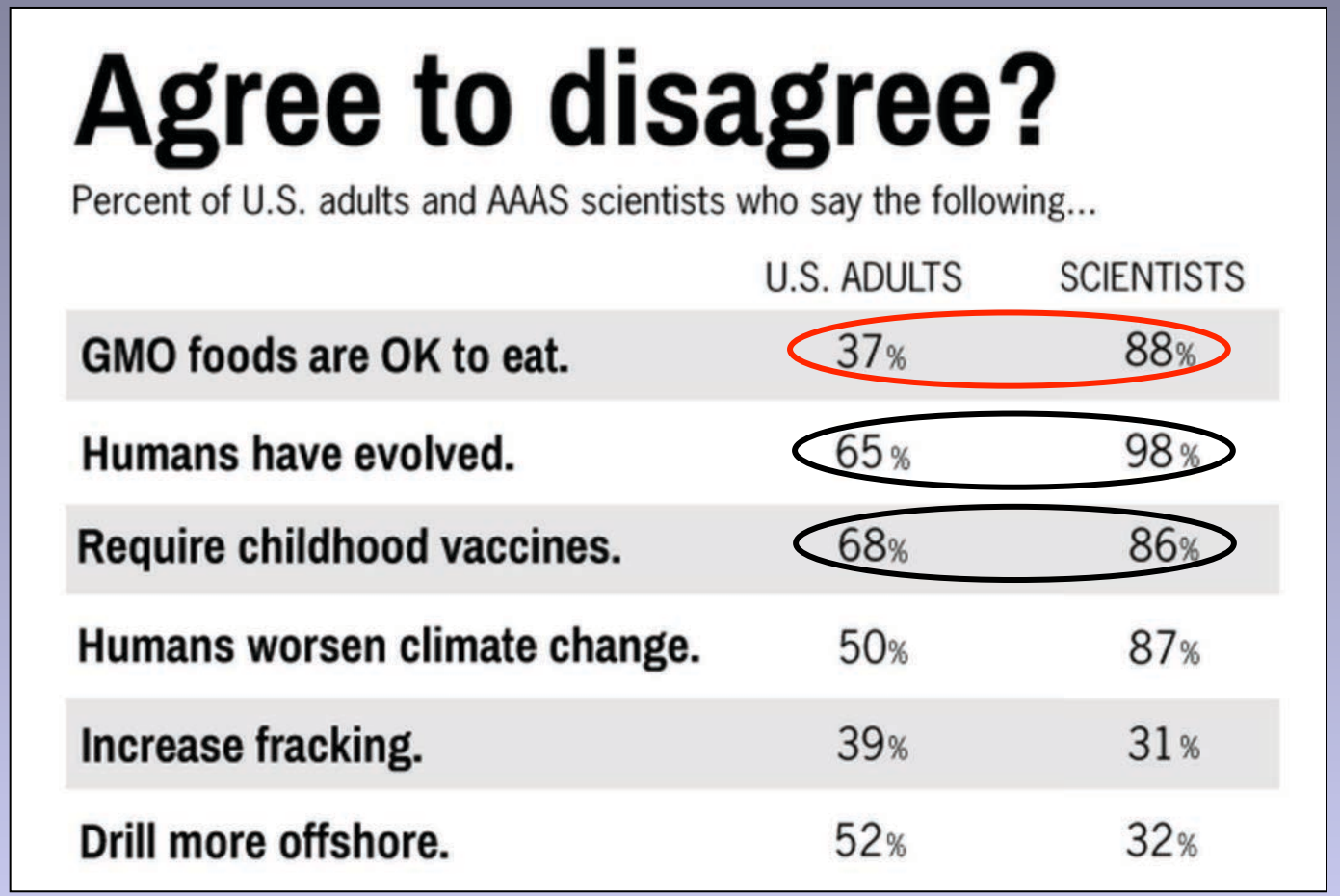
There seems to be angst about many contemporary issues

Consider the March 2015 *National Geographic* article highlighting public concerns and discussing the role science plays in people's thinking about…

- Climate Change
- Evolution
- Vaccination
- Moon Landing
- Genetically Modified Foods, GMO's

Do scientists' views differ from the public's on certain topics?

Yes, views of the public and scientists often disagree



SOURCE: Pew Research Center, January 29, 2015, "Public and Scientists' Views on Science and Society"
http://www.pewinternet.org/2015/01/29/public-and-scientists-views-on-science-and-society/

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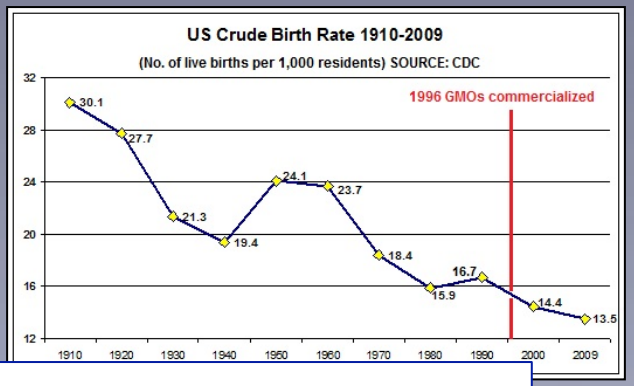
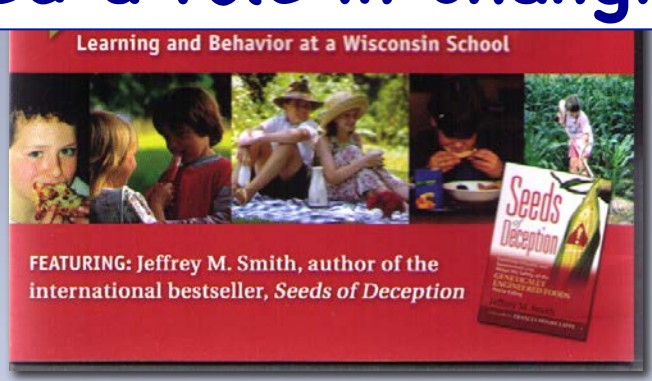
My presentation will focus on issues related to genetically engineered (GE, GMO) crops and animals.



Let's first talk about how genetic modification has historically played a role in changing our foods

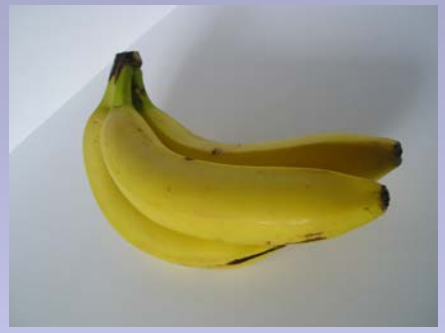


Farmers say pigs and cows became sterile

Do Foods Look Different Today than They Did Before?

Carrot

Eggplant



Modifications happened via spontaneous mutations, intercrossing and natural selection

WHY?

Broccoli, Kale, Cabbage

More recently humans have intentionally modified plants using classical breeding?

Triticum monococcum

Ancient variety

Triticum aestivum

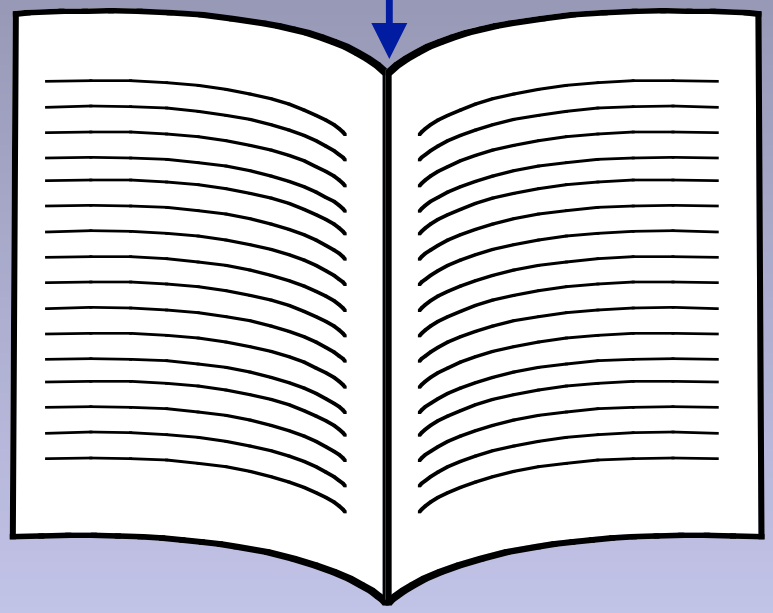
Modern bread variety

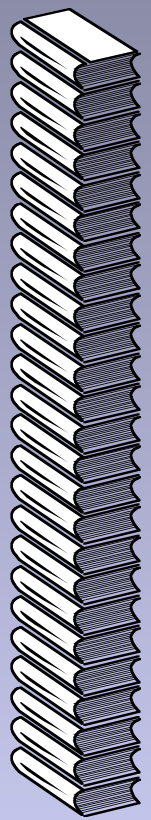
What happens genetically during breeding?

Genetic Information in Cells of Wheat Plant

Chemical units represented by alphabetic letters

...CTGACCTAATGCCGTA...





1700 books
1000 pages each

1700 books
(or 1.7 million pages)

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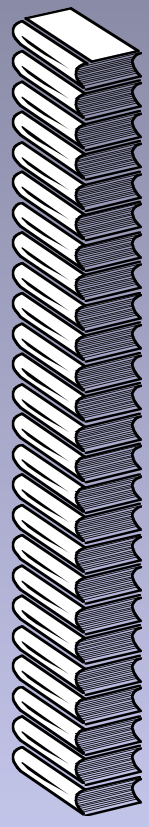
What happens during classical breeding?



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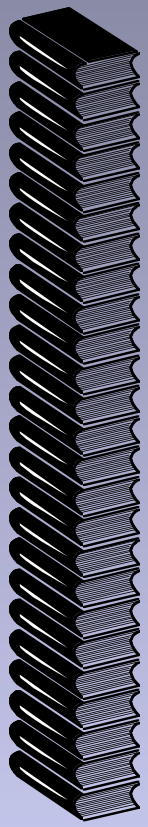

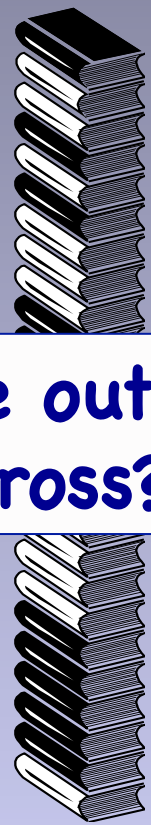

Random retention of ~50% of information from each

What is the outcome of the cross?

1700 books (or 1.7 million pages)

1700 books (or 1.7 million pages)

1700 books (or 1.7 million pages)

Genetic modification that <u>is not</u> GE or GMO

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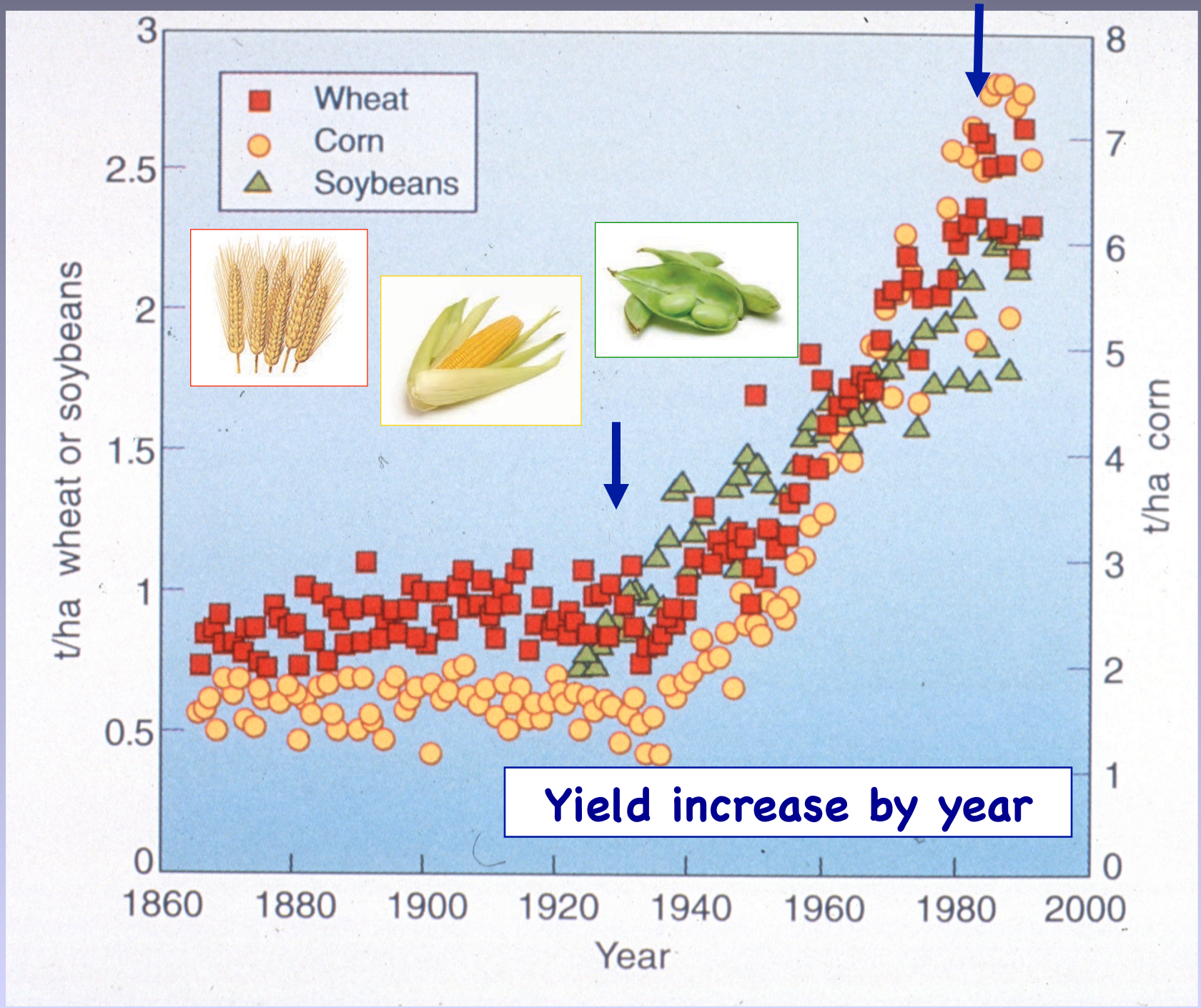
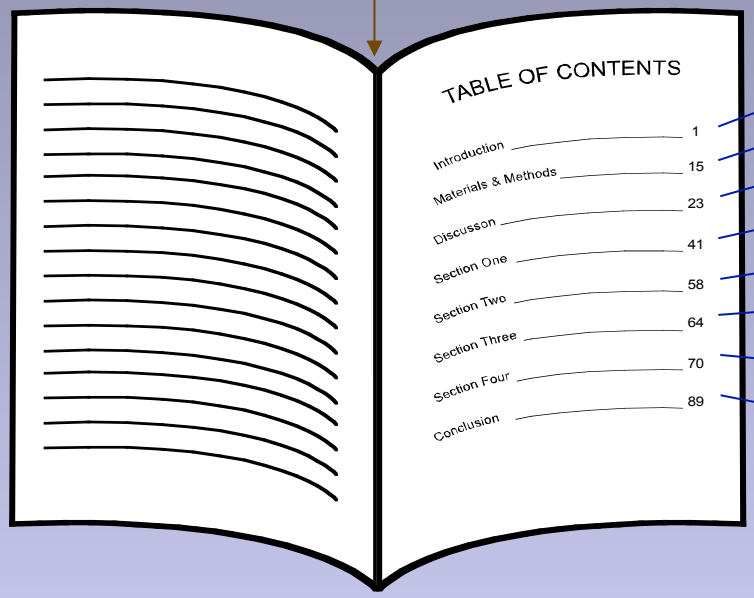
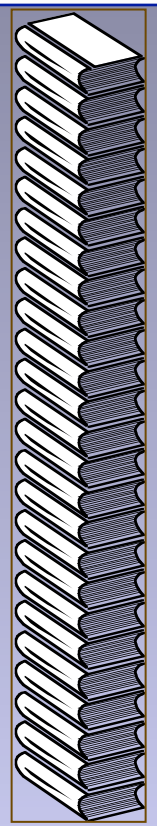

Wheat
Corn
Soybeans
t/ha wheat or soybeans
t/ha corn
Year
0
0.5
1
1.5
2
2.5
3
0
1
2
3
4
5
6
7
8
1860
1880
1900
1920
1940
1960
1980
2000
Yield increase by year

New ways to do breeding...

Uses table of contents of genes (genomics) for marker assisted selection

...CTGACCTAATGCCGTA...





Increases speed of breeding process

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(or 1.7 million pages)

Genetic modification that is not GE or GMO

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Can't We Just Do All Modification This Way?

Marker-assisted selection used to protect rice against bacterial blight and blast disease

Limited to diversity in crop and compatible relatives


What other ways can the modern tools of genetics be used to create new varieties?
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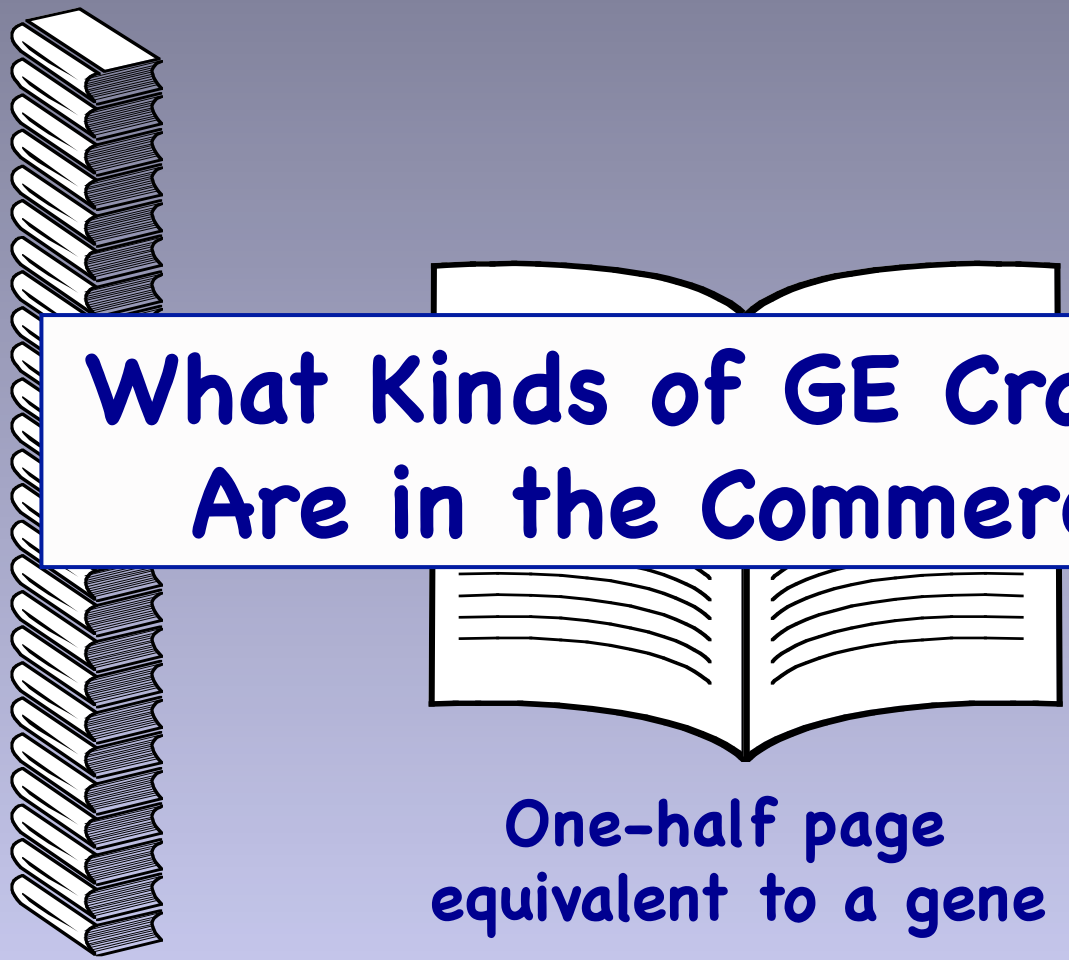
Genetic Engineering



What Kinds of GE Crops and Foods Are in the Commercial Market?

Inserts randomly in genome

Inserted gene(s)

One-half page equivalent to a gene

1700 books
(or 1.7 million pages)

1700 books
(or 1.7 million pages)

Genetic modification that is GE and GMO

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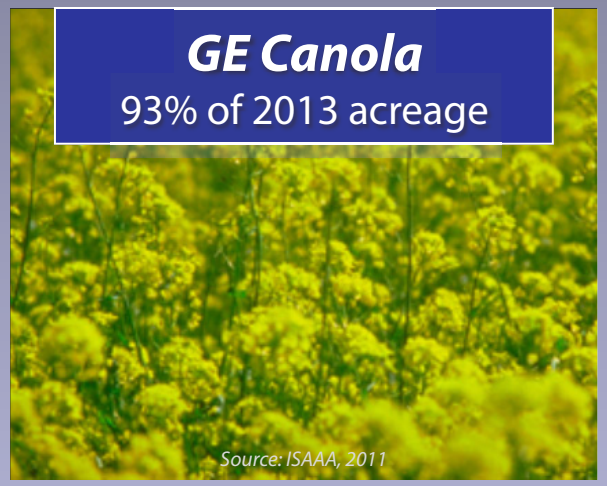
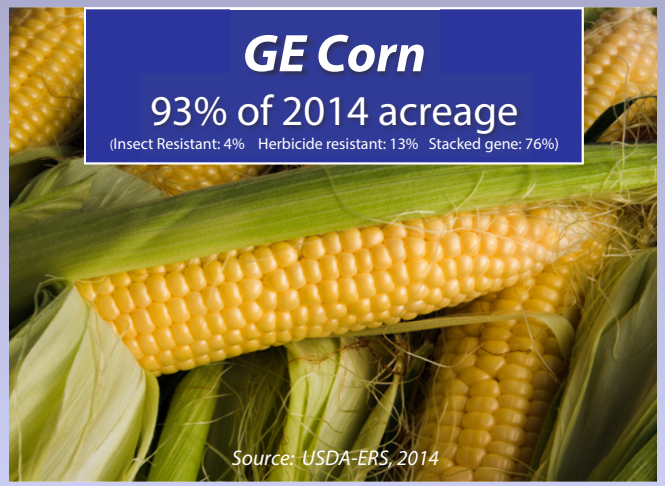
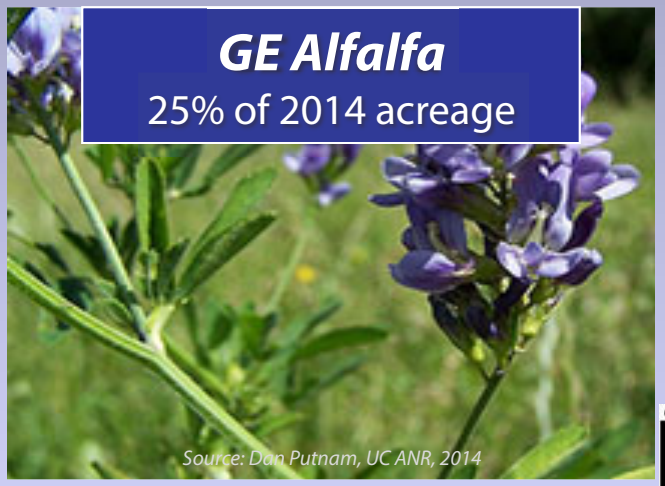
Number of commercial large acreage GE crops in U.S. is limited







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Number of different traits available in large acreage GE crops is also limited

Insect-tolerant Bt crops - engineered for resistance using gene from naturally occurring bacterium

Herbicide-tolerant - engineered with gene to tolerate herbicide application

Crops with stacked traits - both Bt and HT - are available

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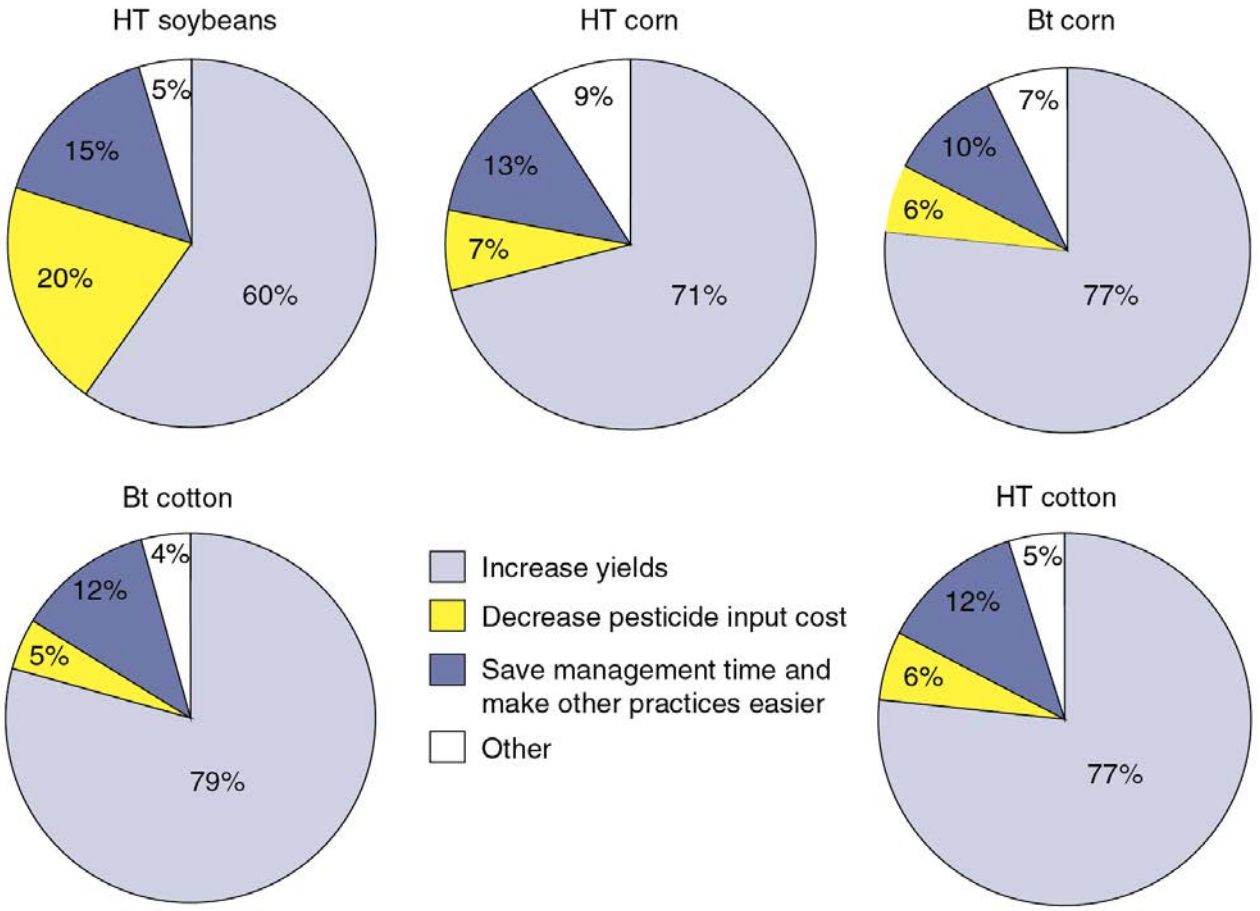
Why do U.S. growers use GE crops?



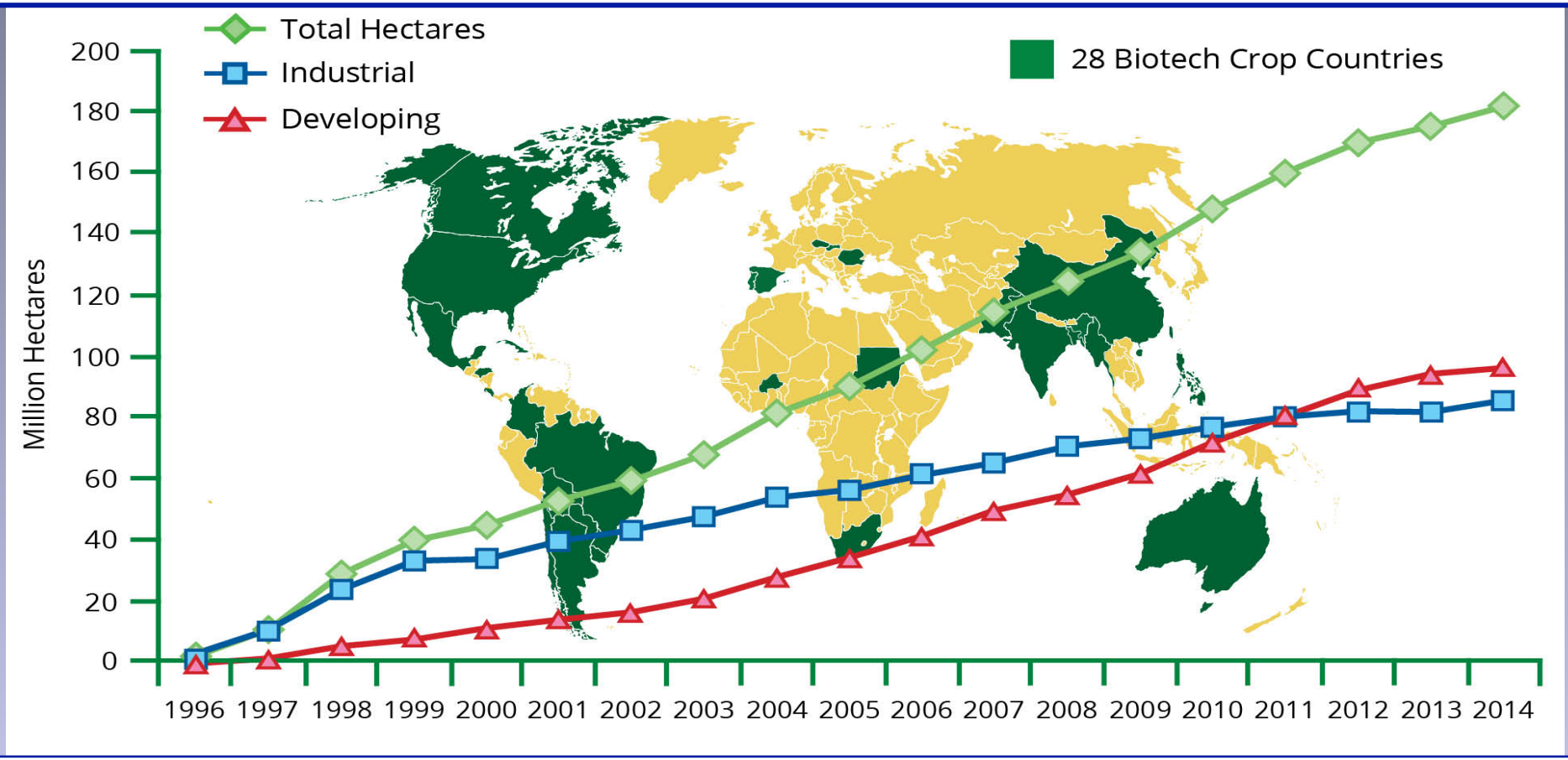
Reasons vary from crop-to-crop but primary reason is improved yields

SOURCE: Fernandez-Cornejo, J., Wechsler, S., Livingston, M. and Mitchell, L. 2014. Genetically Engineered Crops in the United States. USDA Economic Research Service Report No. 162, February 2014.

These types of large-acreage GE crops lead to estimates that 60-80% of processed foods in U.S. have GE ingredients

SOURCE: https://factsaboutgmos.org/disclosure-statement

What about worldwide? Despite limited crop and trait types, acreage is increasing in 20 developing, 8 developed countries

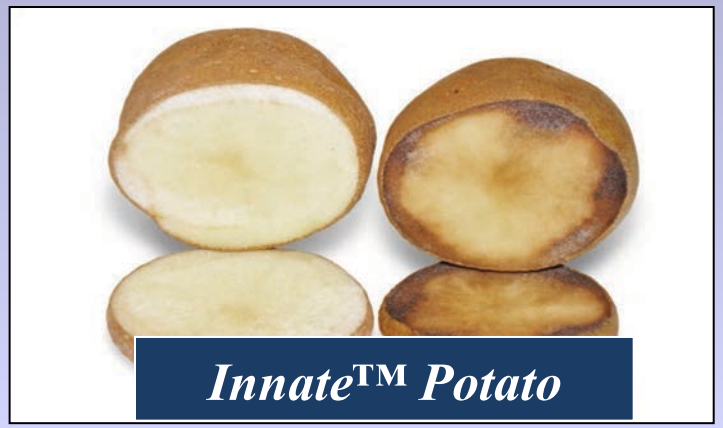


2014: 18 million farmers in 28 countries planted
448M acres (>4X size of California)
>90% small acreage farmers in developing countries

Clive James 2014 http://www.isaaa.org/resources/publications/briefs/46/executivesummary/

There are only a few whole, GE foods that have been commercialized

Two more are just being introduced



WHAT'S IN THE PIPELINE?

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UCD researcher engineers drought tolerance: results in vigorous growth after prolonged drought

Tobacco after 2 weeks without water then 1 week watered

Control, non-GE

GE tobacco

SOURCE: Rivero, R.M., Kojima, M., Gepstein, A., Sakakibara, H., Mittler, R., Gepstein, S. and Blumwald, E. 2007. Delayed leaf senescence induces extreme drought tolerance in a flowering plant. Proceedings of the National Academy of Sciences USA 104: 19631-19636.

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E.U. scientists create potato with gene from wild relative that protects against late blight disease, cause of Irish potato famine

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teagasc
Agriculture and Food Development Authority

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www.amigaproject.eu

Jo KR et al. 2014 Development of Late Blight Resistant Potato by Cis-gene Stacking. BMC Biotechnol

Engineered American chestnut making comeback - engineered with wheat gene to prevents canker; replanted with $104K raised through crowd funding

Coghlan A. 2014. New Scientist "American Chestnut Set for Genetically Modified Revival".

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High anthocyanin purple GE tomatoes. Diets with 10% purple tomatoes increased lifespan of cancer-prone mice

Butelli et al. 2008. https://www.jic.ac.uk/staff/cathie-martin/purple-tomatoes.html

MIT Technology Review

Chinese Researchers Stop Wheat Disease with Gene Editing

Researchers have created wheat that is resistant to a common disease, using advanced gene editing methods.

By David Talbot on July 21, 2014

Advanced genome-editing techniques have been used to create a strain of wheat resistant to a destructive fungal pathogen – called powdery mildew – that is a major bane to the world's top food source, according to scientists at one of China's leading centers for agricultural research.

Wheat resistant to powdery mildew created using new genome-editing techniques

SOURCE: "Chinese Researchers Stop Wheat Disease with Gene Editing", MIT Technology Review, July 21, 2014
http://www.technologyreview.com/news/529181/chinese-researchers-stop-wheat-disease-with-gene-editing/

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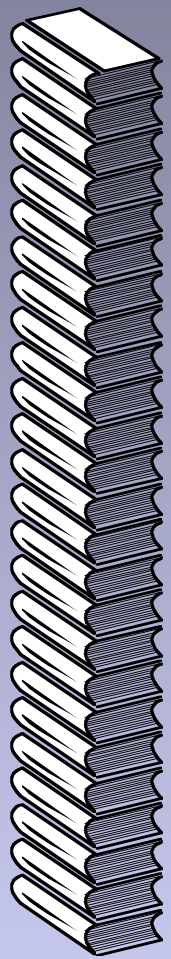
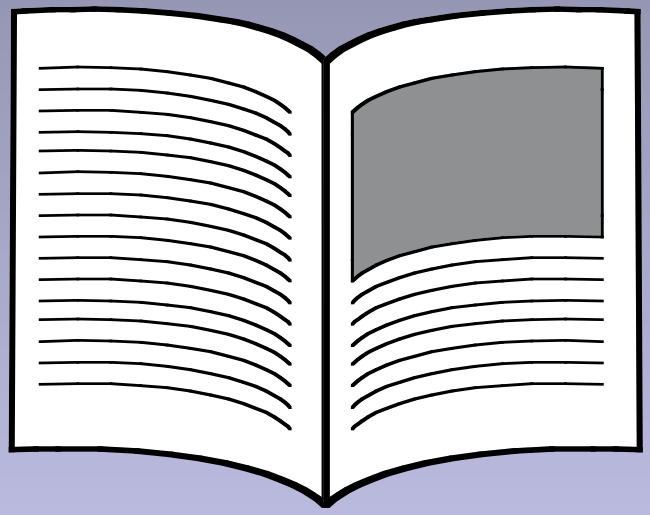
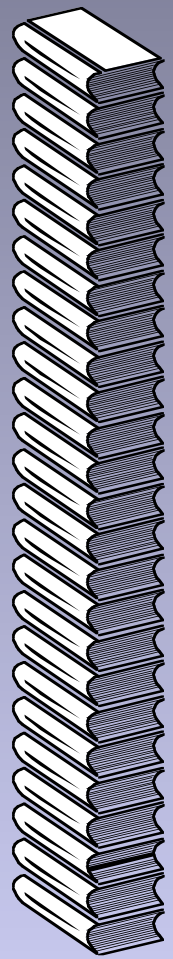
What is Genome Editing?



It is this one sentence which will be modified
It is that new sentence which will be modified



Find target text, cut out, paste in new modified text



Inserts specifically in genome

Insert gene edits

1700 books (or 1.7 million pages)

Genome editing is not GE or GMO

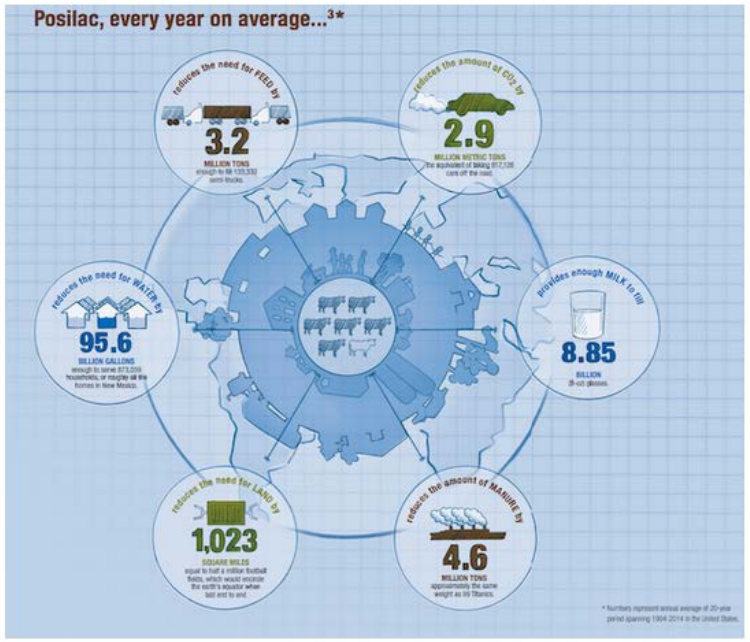
1700 books (or 1.7 million pages)

What is happening with animals?

DAIRY UPDATE ...

Posilac celebrates 20 years aiding dairy

New report details economic, environmental value for dairy industry



While global dairy productivity has doubled in the past 50 years, there's 14 percent less milk available per person today than in 1961.

Engineered microbe produces rBST for dairy, introduced in 1994 before GE crop products

- *Used on 37M cows over 20 years*
- *Reduced costs by $6.3 B*
- *Leads to 10 lbs more milk per day*

What else has been engineered?

SOURCE: "Posilac celebrates 20 years aiding dairy", Morning Ag Clips, February 13, 2014. http://www.morningagclips.com/index.php?cID=6011#.UwPBrkJdVLO

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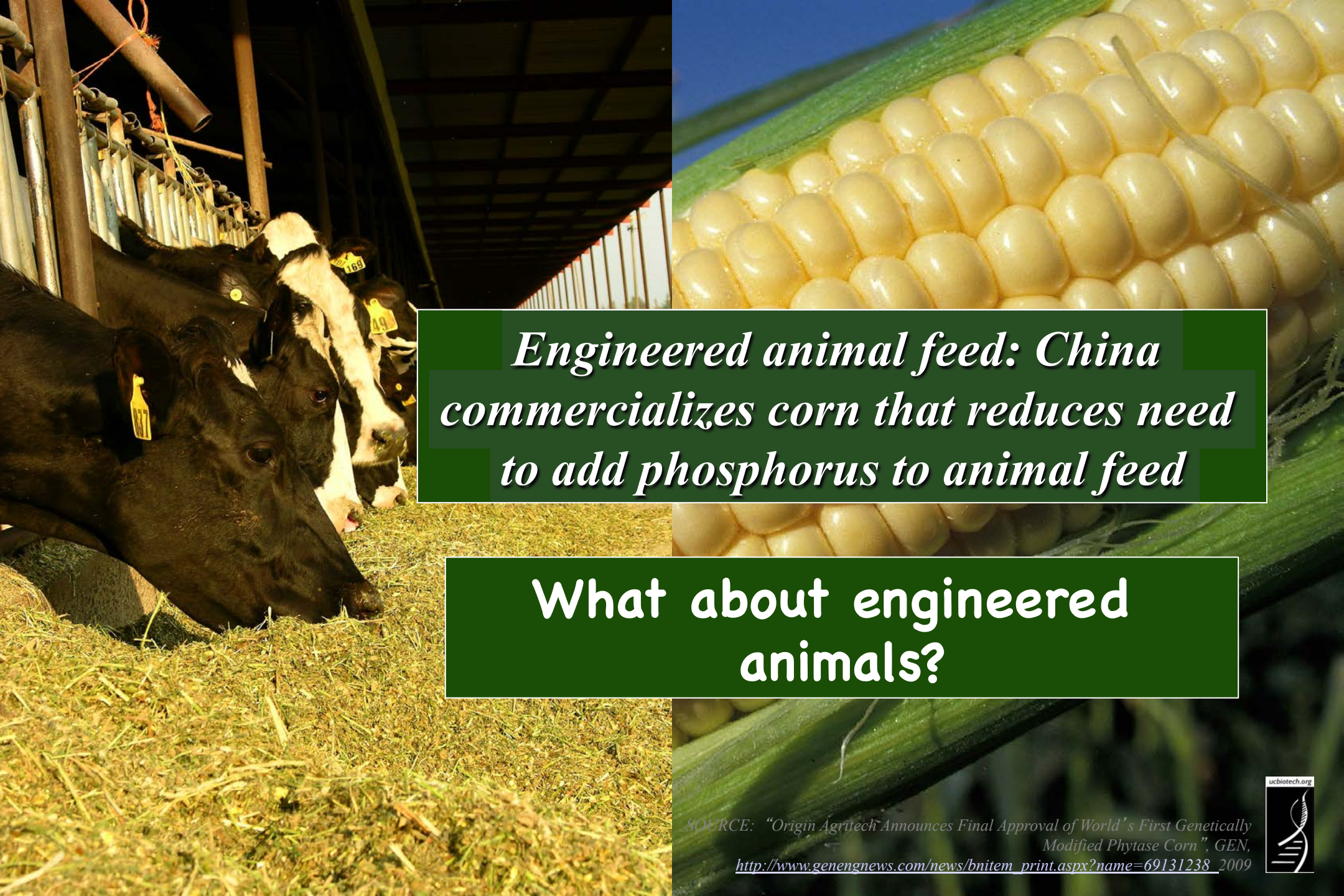

Engineered animal feed: China commercializes corn that reduces need to add phosphorus to animal feed

What about engineered animals?

SOURCE: "Origin Agritech Announces Final Approval of World's First Genetically Modified Phytase Corn", GEN, http://www.genengnews.com/news/bnitem_print.aspx?name=69131238 2009

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USDA United States Department Of Agriculture
Agricultural Research Service

ars

Transgenic Cows Resist Mastitis-Causing Bacteria

By Rosalie Marion Bliss
April 4, 2005

WASHINGTON, April 4--U.S. Department of Agriculture researchers have used gene-transfer te
called mastitis.

"This research is an important first step in understanding how genes can be used to protect anima
Research Service (ARS).

This scientific discovery, published in the current edition of Nature Biotechnology, demonstrates t
Currently, vaccines, antibiotics and a cow's own immune system cannot effectively fight the bacte

A scientific team led by Robert J. Wall, an animal physiologist with the ARS Biotechnology and Ge
produced using recombinant DNA technology--that includes the genetic code for producing a natu

While all milk contains several naturally occurring antimicrobial proteins, such as lysozyme and la


2012: Engineering downregulation of major milk allergen in calf reduces potential for allergic responses in humans
SOURCE: Jabed, A., Wagner, S., McCracken, J., Wells, D.N. and Laible, G.. 2012. Targeted microRNA expression in dairy cattle directs production of b-lactoglobulin-free, high-casein milk. Proceedings of the National Academy of Sciences USA, published ahead of print October 1, 2012, doi:10.1073/pnas.1210057109.
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2015: Chinese scientists engineer cows with mouse gene to protect against tuberculosis

SOURCE: "Tuberculosis-resistant cows engineered in China", Popular Science, 3/4/15.
http://www.popsci.com/tuberculosis-resistant-cows-bred-china

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Triploid, all-female genetically engineered Atlantic salmon (AquAdvantage Salmon), grown-out only in the physically-contained freshwater culture facilities

FDA approved AquAdvantage Salmon for consumption on November 19, 2015

SOURCE: "GE salmon draft environmental assessment released", Crop Biotech Update, 1/23/13
http://www.isaaa.org/kc/cropbiotechupdate/article/default.asp?ID=10554

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U.S. Regulatory Agencies

How Are All of These Things Regulated?

USDA

- Field testing
  - -Permits
  - -Notifications
- Determination of non-regulated status

FDA

- Food safety
- Feed safety

EPA

- Pesticidal plants
  - -tolerance exemption
  - -registrations
- Herbicide registration

Plant pest?

Danger to people?

Risk to environment?

What are some issues with GE crops?

What are some food safety issues?

- Regulatory oversight
- Lack of peer-reviewed food safety tests
- Consumer attitudes and labeling

What are some food safety issues?

- Regulatory oversight
- Lack of peer-reviewed food safety tests
- Consumer attitudes and labeling

Outdated regulatory system, created in 1986, causing problems:

- New products emerge with no rules to govern them
- Old products are not on the market because there are no clear pathways for commercialization
- New products created to step around regulatory system

EXAMPLES:

nature

NATURE | NEWS

Gene-edited CRISPR mushroom escapes US regulation

Jose A. Bernat Bacete/Getty Images

Dupont Develops Corn Using New CRISPR Technology

By KRISTOFOR HUSTED • APR 27, 2016

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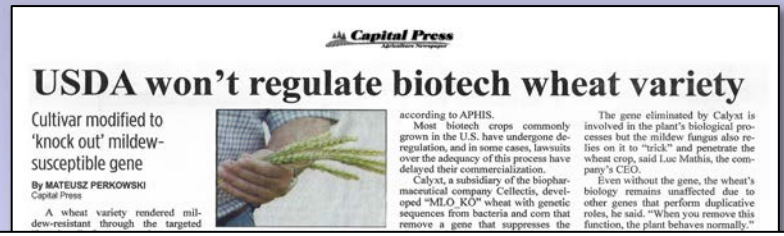
LIZ WEST, FLICKR CREATIVE COMMONS

A new genetically engineered corn variety developed by one of the world's largest seed companies won't undergo the same review by regulators as other GMO crops.



Capital Press

USDA won't regulate biotech wheat variety

Cultivar modified to 'knock out' mildew-susceptible gene

By MATEUSZ PERKOWSKI
Capital Press

A wheat variety rendered mildew-resistant through the targeted

according to APHIS.

Most biotech crops commonly grown in the U.S. have undergone deregulation, and in some cases, lawsuits over the adequacy of this process have delayed their commercialization.

Calyxt, a subsidiary of the biopharmaceutical company Cellectis, developed "MLO_KO" wheat with genetic sequences from bacteria and corn that remove a gene that suppresses the

The gene eliminated by Calyxt is involved in the plant's biological processes but the mildew fungus also relies on it to "trick" and penetrate the wheat crop, said Luc Mathis, the company's CEO.

Even without the gene, the wheat's biology remains unaffected due to other genes that perform duplicative roles, he said. "When you remove this function, the plant behaves normally."

- April 2016: USDA APHIS decided not to regulate a mushroom and corn genetically modified with CRISPR-Cas9 genome editing. Reason: no DNA from other species introduced.

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These types of examples have resulted in loud calls for revamping U.S. regulatory oversight

Genetically engineered crops that fly under the US regulatory radar

A first step taken on July 2, 2015 by a White House Initiative to modernize biotech regulation

the scope of its regulations several genetically

Coordinated Framework is on the one hand

Charge: update 1986 Coordinated Framework to clarify roles of three agencies to determine what products fall under authority of what agencies.

of entities seeking nonregulated status for

US regulatory framework for GE crops and

Also need to decide how to regulate products created with genome editing tools.

as null segregants, novel delivery systems,

small companies and public sector institutions.

Camacho et al. 2014. Nature Biotech. 32:1087-1091

What are some food safety issues?

- Regulatory oversight
- Lack of peer-reviewed food safety tests
- Consumer attitudes and labeling

Occasionally there are widely publicized studies that cast doubt on safety of GE foods - one published by French researcher in Sept. 2012

Later reviewed by European Food Safety Authority and found to have no merit

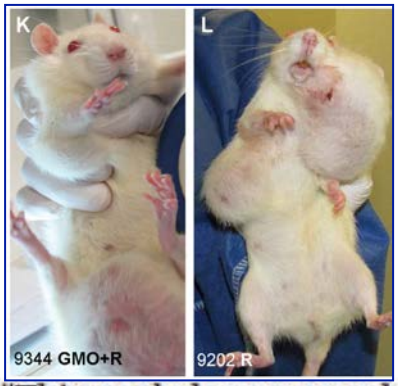
But did you ever hear that on Dr. Oz?

French academies trash GM corn cancer study

By **RFI**

A controversial study that linked genetically modified maize to cancer in la... six ... in a...

Featured on Dr. Oz Show



Claim that Monsanto's RR corn causes tumors in rats

The report's author, Gilles-Eric Séralini, with his book All Guineapigs
AFP /Jacques Demarthon

"This work does not enable any reliable conclusion to be drawn," they say, adding that the publicity surrounding the publication has "spread fear among the public."

The joint statement - an extremely rare event in French science - is unsigned and issued in th... names of the national academies of agriculture, medicine, pharmacy, science, technology and... veterinary studies.

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What have other published studies shown?

Meta-analysis from France in 2012 showed GE foods are nutritionally equivalent to non GE foods and can be safely consumed in food and feed.

Based on 12 long-term (>90d to 2yr) and 12 multigenerational (2 to 5 generation) feeding trials of GE feed in animals

maize

potato

soy

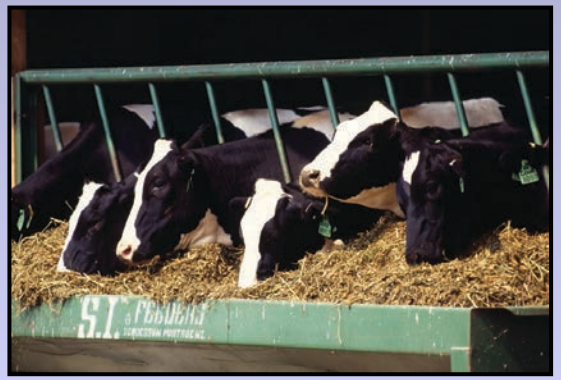
rice

triticale

SOURCE: Snell C, Bernheim A, Berge J-P, Kuntz M, Pascal G, Paris A, Ricroch AE. 2012. Assessment of the health impact of GM plant diets in long-term and multigenerational animal feeding trials: A literature review. Food and Chemical Toxicology 50: 1134-1148.

2014 study

- 9 B food-producing animals in U.S
- 95% consumed feed with GE ingredients
- Analysis of publically available data from 1983 to 1996, before GE crops, versus 1996 to 2011, included >100 B animals
- Conclusion:
  - No unfavorable or perturbed trends in livestock health and productivity.
  - No differences in nutritional profile of animal products from GE-fed animals.



SOURCE: "**Prevalence and impacts of genetically engineered feedstuffs on livestock populations**"
A. L. Van Eenennaam and A. E. Young, *J. Animal Science* September 2014

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What are some food safety issues today?

- Regulatory oversight
- Lack of peer-reviewed food safety tests
- Consumer attitudes and labeling

Label: ``From cows not treated with rBST/rBGH''

USDA Guideline: "The producer of a product labeled with rbST claims should be able to demonstrate that all milk-derived ingredients in the product are from cows not treated with rbST."

What It Means: This label refers to recombinant bovine somatotrop
hormone (r
Producers
hormones to their dairy cows.

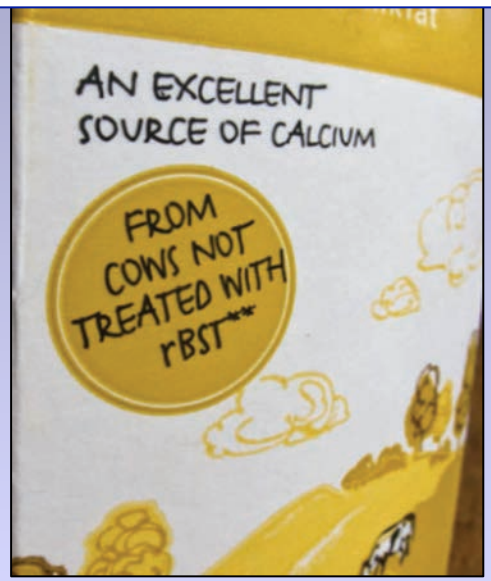
What It *Doesn't* Mean: This label doesn't mean that the milk

cows that receive supplemental bST and milk from cows that do not". Other groups, such as the American Cancer Society, call the current research inconclusive, and its use is not permitted in the European Union and Canada. Like all animals, dairy cows naturally produce a number of other hormones, including estrogen.

Verified by: Labeling for rBST and rBGH is overseen by the USDA. To obtain USDA Process Verified certification, producers must submit documentation of farming practices, feeding plans and related information to the USDA that shows they are in compliance with the labeling claim. Products with a USDA Organic label, which is verified by third-party auditors, are not allowed to use rBGH.

What does the milk label mean?

Milk had to address the labeling issue long before GE foods



The Columbia
SCIENCE AND TECHNOLOGY LAW REVIEW

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Labeling Milk from Cows Not Treated with rBST: Legal in all 50 States as of September 29th, 2010

Posted on October 28, 2010 by Libby Moulton — 21 Comments ↓

Under the Food, Drug and Cosmetic Act and accompanying regulations, the Food and Drug Administration (FDA) is charged with promulgating regulations pertaining to false or misleading to consumers. Until earlier this fall, the FDA's determination that milk from cows treated with artificial growth hormones was the same as milk from untreated cows had never been challenged by a court. In International Dairy Foods Association v Boggs, the 6th circuit found that the two milks are in fact different, disregarding the FDA's prior determination, and struck down an Ohio regulation prohibiting milk producers from labeling milk as coming from non-treated cows.

What about GE foods from plants?

Thinking about your diet over the past few months, are there any foods or ingredients that you have avoided or eaten less of?

	Jan. 2001	Apr. 2003	July 2006	Apr. 2010	Apr. 2014
• Yes	54%	53%	59%	54%	53%
• No	46%	46%	40%	46%	47%
• Don't Know/Refused	0%	1%	1%	0%	0%

SOURCE: IFIC, April 2014.
*http://www.foodinsight.org/Press-Release/Detail.aspx?topic=Survey_Finds_Continued_Support_for_FDA_s_Biotech_Foods_Labeling_*

What food or ingredients did you avoid or eat less of?

	Jan. 2001	July 2006	Apr. 2010	Apr. 2014
• Sugars	31%	50%	51%	55%
• Fats/cholesterol	41%	33%	32%	26%
• Animal products	28%	28%	18%	25%
• Other	9%	11%	14%	N/A
• Snacks/Fast food	N/A	16%	16%	20%
• Salt/spices	11%	12%	20%	18%
• Caffeine	4%	N/A	N/A	N/A
• Soda	4%	N/A	N/A	N/A
• Genetically engineered	0%	0%	0%	2%

SOURCE: IFIC, April 2014.
*http://www.foodinsight.org/Press-Release/Detail.aspx?topic=Survey_Finds_Continued_Support_for_FDA_s_Biotech_Foods_Labeling_*

Can you think of any information that is not currently included on food labels that you would like to see on food labels? And what types of information would that be?

	Jan. 2001	Apr. 2003	July 2006	Apr. 2010	Apr. 2014
• Yes	26%	17%	18%	18%	26%
– Ingredients (i.e., fats, salt)	6%	4%	3%	20%	23%
– Other	11%	9%	5%	25%	4%
– Genetically altered	2%	2%	1%	0	0
• No	74%	77%	82%	82%	74%
• Don't know/refused	--	6%	--	--	14%

Open-ended poll that doesn't use term, GMO

SOURCE: IFIC, April 2014.
*http://www.foodinsight.org/Press-Release/Detail.aspx?topic=Survey_Finds_Continued_Support_for_FDA_s_Biotech_Foods_Labeling_*

What if you ask people directly about labeling of GMO foods?

May 2016 Harris Poll
When asked if they supported labeling legislation for G.M.O.'s:

75% of respondents, yes
9% no
16% didn't know

SOURCE: Harris Poll Finds Support for Federal G.M.O. Labeling. Food Business News May 26, 2016

Food Safety News

Breaking news for everyone's consumption

GE Labeling Resurrected in California, Petition For Ballot Measure Circulating in Colorado

BY **DAN FLYNN** | MARCH 25, 2014

California's 2012 food-labeling ballot measure, rejected by state voters, makes a return from the grave tomorrow with a public hearing in Sacramento. And another state initiative is in the offing in Colorado.

Since the narrow loss for the Golden State's Proposition 37, which called for labeling foods made with genetically modified organisms (GMOs), almost half the states have seen bills introduced containing similar

by early August.

This has led to numerous statewide labeling laws for GE foods that could lead to a patchwork of regulation – causing problems for commerce and enforcement

SOURCE: "GE Labeling Resurrected in California, Petition For Ballot Measure Circulating in Colorado", March 25, 2014, Food Safety News. http://www.foodsafetynews.com/2014/03/gm-labeling-resurrected-in-california-petition-circulating-for-initiative-in-colorado/#.UznX9q1dVLM

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While waiting for federal laws, there are non-legislative labeling efforts, like the popular Non-GMO Project label

SOURCE: "GMO Labeling: These Numbers Will Astound You", The Motley Fool, 2/7/15
http://www.fool.com/server/printarticle.aspx?file=/investing/general/2015/02/07/gmo-labeling-these-numbers-will-astound-you.aspx

SOURCE: Costanigro, M. and Lusk, J.L. 2014. The signaling effect of mandatory labels on genetically engineered food. Food Policy 49: 259-267

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Another option: "USDA offers to verify food companies' claims that products contain no GMO's"

"This decision adds GE ingredients to the agency's audit program that verifies various food claims, e.g., grass-fed, antibiotic-free and humanely raised. Program is voluntary. Producers asking for non-GMO verification will pay a fee"

SOURCE: "U.S. action on GMOs stops far short of mandatory labels", San Francisco Chronicle, 5/14/15. http://www.sfgate.com/science/article/U-S-plan-to-vouch-for-GMO-free-foods-disappoints-6264407.php

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SFGATE

General Mills to add GMO labeling or

By Tara Duggan Updated 4:36 pm, Friday, March 18, 2016

In a striking reversal for big food manufacturers, which have spent n
quire mandatory labeling of genetically engineered food, General Mi
voluntarily add that information to its labels.

General Mills' move is a reaction to a law due to go into effect July 1
tory labeling of foods with genetically modified organisms. On Wedn
by Sen. Pat Roberts, R-Kan., to preempt Vermont's law by making t
Jeff Harmening, executive vice president and chief operating officer for U.S. retail at General Mills, ex-
plained the Minneapolis company's move in a blog post.

With the Vermont labeling law set for July 1, companies were left with a decision.

"We can't label our products for only one state without significantly driving up costs for our consumers, and we simply will not do that." General Mills

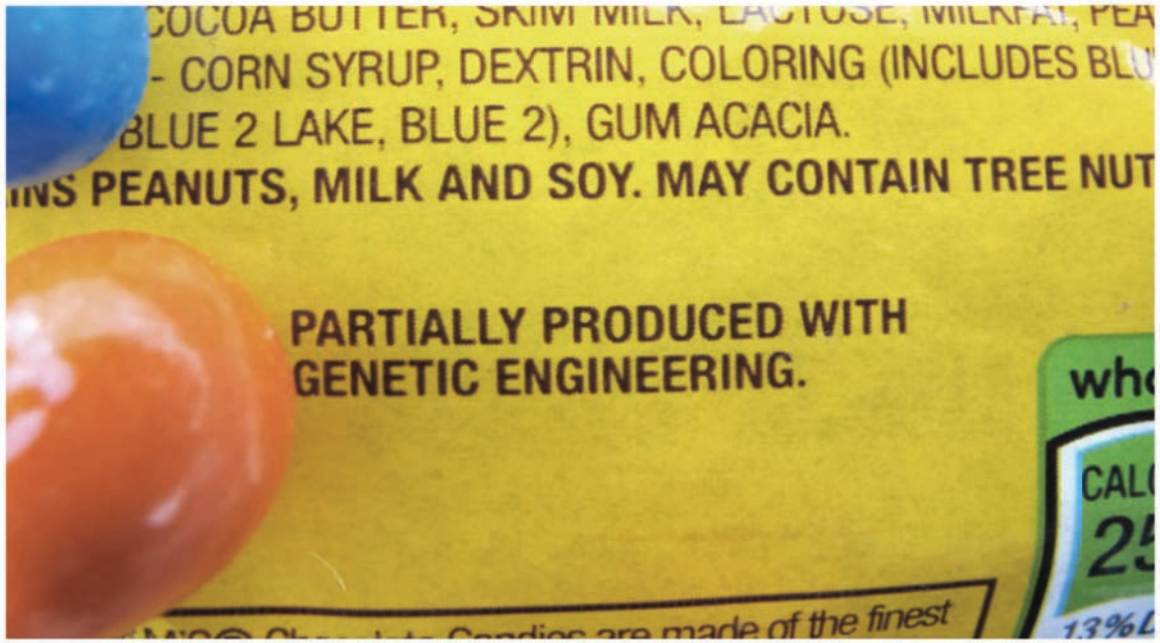
Others: Campbell's Soup Co., Mars, Kellogg's and ConAgra Foods have said they will label food with GMOs in time to comply with Vermont's deadline and compatible with the law's standards.

SOURCE: "General Mills to add GMO labeling on its products", SF Gate, 3/18/16
http://www.sfgate.com/food/article/General-Mills-to-add-GMO-labeling-on-its-products-6922250.php

Senators Reach Deal On National GMO Labeling Bill

June 23, 2016 · 6:39 PM ET

PEGGY LOWE



A new disclosure statement on a package of peanut M&Ms candy notes they are "partially produced with genetic engineering."

Hot off the press…

June 23, 2016: Senators Pat Roberts (R, KN) and Debbie Stabenow (D, MI) proposed a bill to set a mandatory national system for GM disclosures on food products. If passed, would nullify the Vermont labeling law, which takes effect July 1, 2016

Under the plan, food companies would be required to disclose which products contain

how they make that disclosure: They could place text on food packaging, provide a QR (Quick Response) code, or direct consumers to a phone number or a website with more information.

Clearly the labeling issue is not yet resolved.

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Where to get more information on the issues?